Centre for Energy and Environmental Markets

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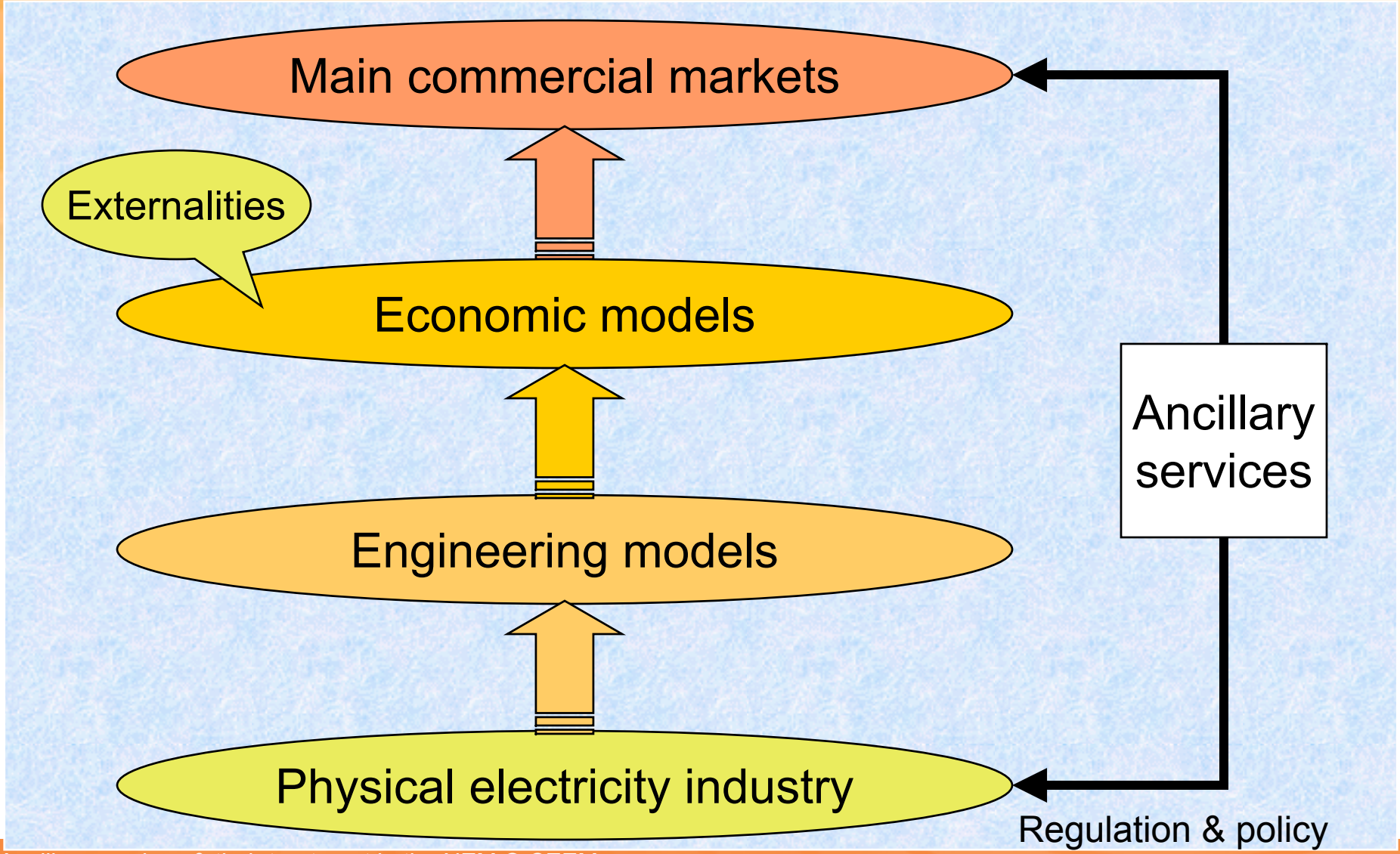
Ancillary services & their treatment in the NEM

Fundamentals of the Australian Competitive Electricity Industry

17-19 August 2005

Trading in electricity:- an abstraction from reality



A model of electricity trading

- Spot market energy traded as a commodity:
  - Energy (that meets QOS criteria) traded during each (short) spot market interval
- Financial instruments:
  - Related to future spot market prices:
    - Convey expectations of future spot market behaviour
    - Allow risk management
- Ancillary services:
  - To manage availability & quality of supply

Managing quality of supply

- ‘Quality of Supply’ (QOS) attributes:
  - Voltage, frequency, waveform purity, phase balance, supply availability *at each node*
- Managed by:
  - ‘Ancillary services’ (AS) in the short term:
    - Appropriate resources under automatic control
  - Projections of future supply-demand balance
  - Investments in new resources as required
- Via appropriate commercial arrangements

Key attributes from the perspective of operation & control

- Size & location:
  - Small resources may only be useful locally
- Flexibility & responsiveness:
  - Start time (hot & cold), ramp rate limit (up/down)
- Cost structure:
  - Start & operating cost (often non-linear)
- *In traditional power system, assume data is "objectively correct"*
- *In a restructured industry, assume data biased & use competitive pressure to "reveal preferences"*

Indicative control capabilities

Technology	Controllable?	Start-up time	Ramp-rate limit
Steam cycle	Yes	5-24 h	+5%/min
CT	Yes	5 min	+20%/min
Hydro	Yes	1 min	+50%/min
Wind	No	-	-
Solar	No	-	-
Load	Yes	1sec	100%/sec

Demand-side participation & projected low reserve conditions (NEMMCO SOO Executive Summary, 2004)

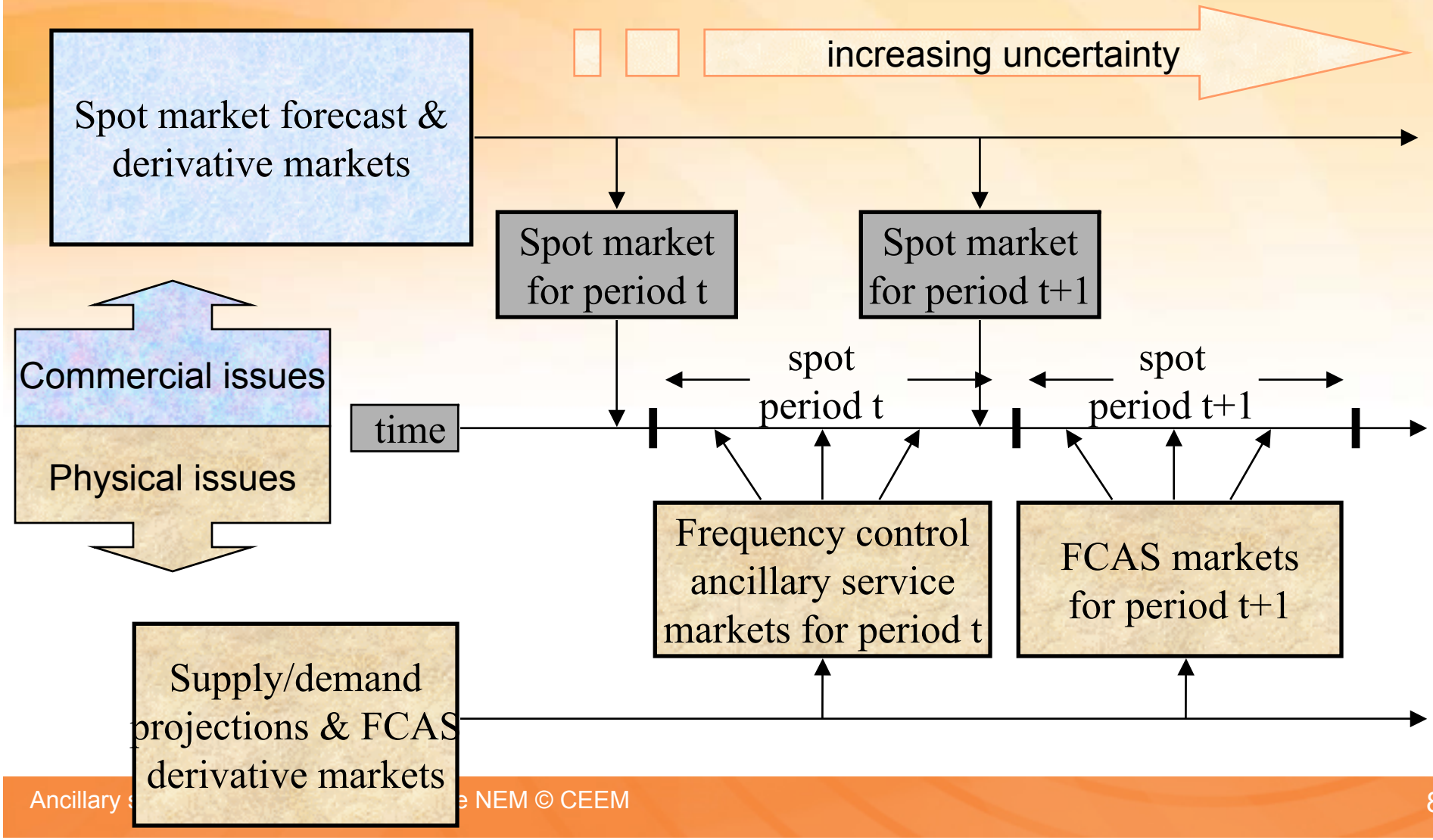
Table 4 Demand-side Participation (MW)

	Committed
Queensland	157
New South Wales	14
Victoria/South Australia	163
Tasmania	0

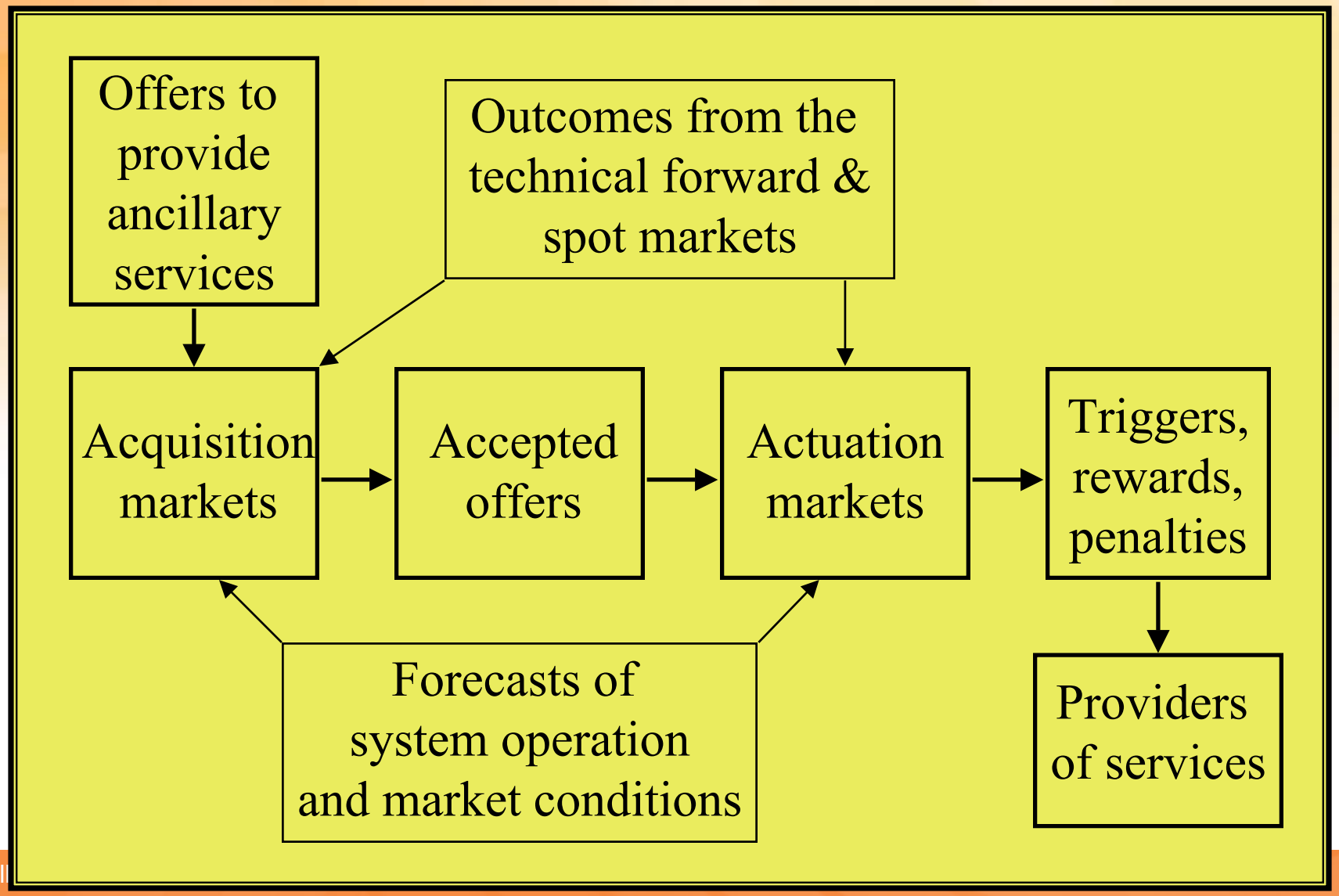
Table 5 Projected Low Reserve Conditions

	LRC Point	Reserve Deficit
Queensland	2009/10	132 MW
New South Wales	2008/09	157 MW
Victoria/South Australia (combined)	2004/05[1] 2006/07	356 MW 321 MW
Tasmania	Beyond 2013/14	–

Managing supply-demand balance in NEM



AS acquisition & actuation markets



AS Acquisition market design

- Offer to provide a service:
  - Capability statement, e.g:
    - max, min & rate of change limits
    - required lead time (starting time)
    - Minimum running time
    - dependence on acceptance of spot offer
  - ‘Willingness to provide’ functions:
    - for readiness
    - for actuation
  - Valid time period of offer

AS Actuation market design

- Mainly by automatic control functions, e.g :
  - Governor, voltage regulator, AGC, economic dispatch, transformer tap changers
- Same market interval as spot market
- Requirement determined by evolving system operation:
  - Notify market participants of evolving conditions in real time to enhance responsiveness

AS Actuation market design

- Initialised by outcomes of AS acquisition & spot markets:
  - Determine parameters & set points for control systems
  - Accepted spot market quantities provide a basis for assessing participants' AS activity
- Financial outcome resolved after the relevant spot market closes

Potential for commercial trading

- Voltage, frequency, short term availability:
  - √ Competition to provide services (technical efficiency)
  - √ Willingness to pay for services (allocative efficiency)
  - √ Transition to a spot market solution if need is prolonged
- Power system security:
  - ? Market valuation of security
  - ? Competition to provide services

Potential for commercial trading

- Waveform purity & phase balance:
  - Potential for competition in provision in service
  - Standards likely to define target outcome
  - Payment likely to be by regulated cost allocation
- Potential reduction in QOS requirements:
  - Short-term QOS excursions often acceptable:
    - 1% voltage reduction causes ~ 1% load reduction
    - 1% frequency reduction causes ~ 2% load reduction
  - Consumers may find cost effective alternatives:
    - uninterruptible power supplies, insurance

Physical vs financial risk management

- Ancillary services are physical means for risk management
- 'Financial instrument' alternatives, e.g:
  - Insurance against damage caused by loss of QOS
  - Call options used to finance rapid start generators:
    - could operate in both spot & ancillary service markets
- Such alternatives enhance contestability in the provision of ancillary services

NEM definition of ancillary services
(a wholesale market approach)

- Those services that provide for:
  - Power system security
  - Quality of supply
  - Enhanced spot trading benefits:
    - Where not provided on the basis of spot prices alone
- NEM categories of ancillary service:
  - Frequency control ancillary services (FCAS)
  - Network control ancillary services (NCAS)
  - System restart ancillary services (SRAS)

Cost of NEM ancillary services in 1999

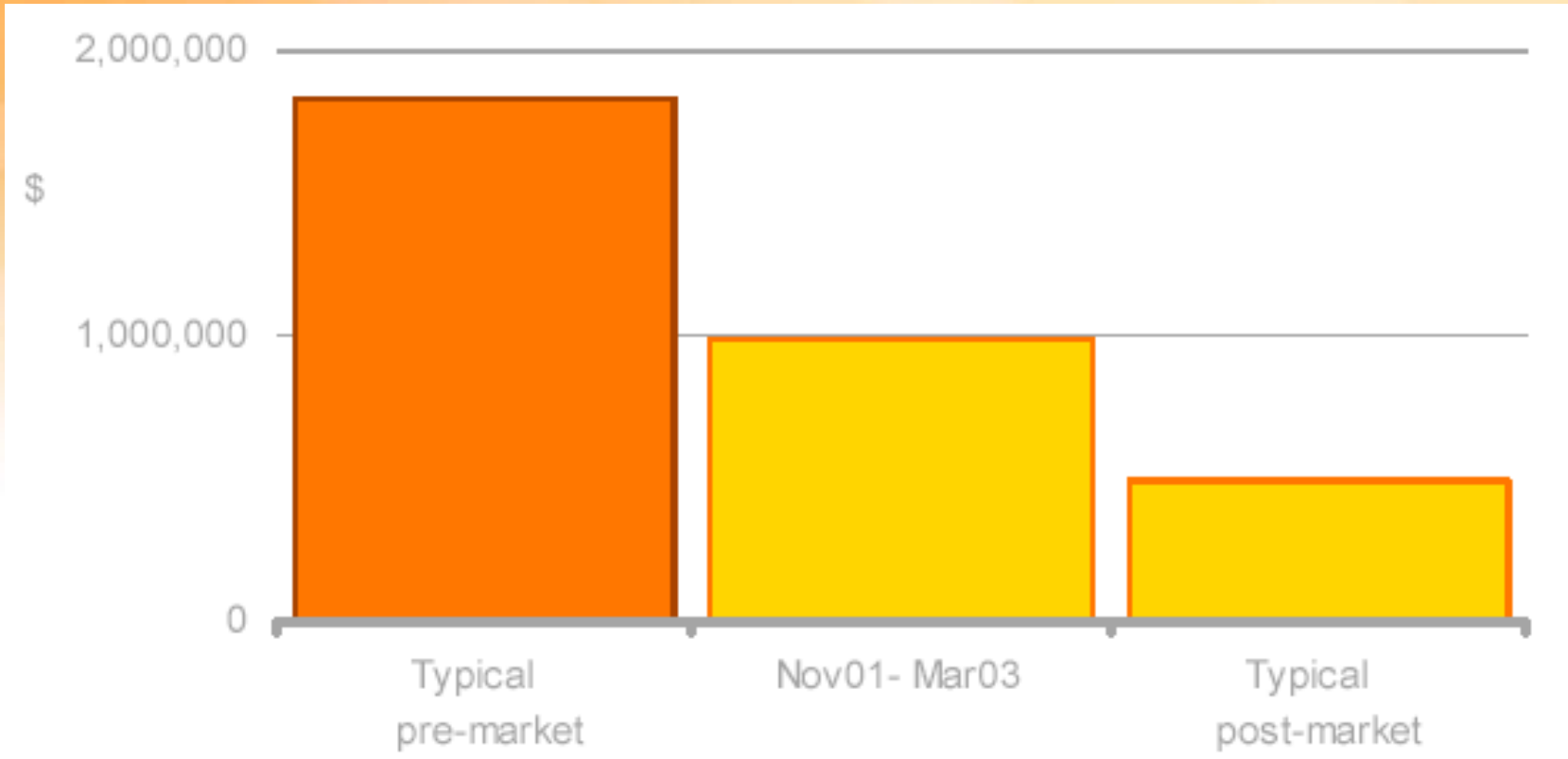
- Overall cost ~ $130 Million pa (1999):
  - Less than 1% of the delivered cost of electricity
- Breakdown of NEM ancillary service costs:
  - Frequency control ancillary services: ~65%
  - Network control ancillary services: ~25%
  - System restart ancillary services: ~10%

NEM frequency control ancillary services

- Frequency management - small deviations:
  - Maintain frequency within normal band & control time error
  - *Two markets (raise & lower regulation) from 10/01*
- Frequency management - large deviations:
  - Large step changes in demand
  - Loss of largest single generator
  - Multiple contingencies
  - *Six markets from October 2001: 6 sec; 60 sec; 5 min raise & lower*

FCAS cost $/week before & after 10/01

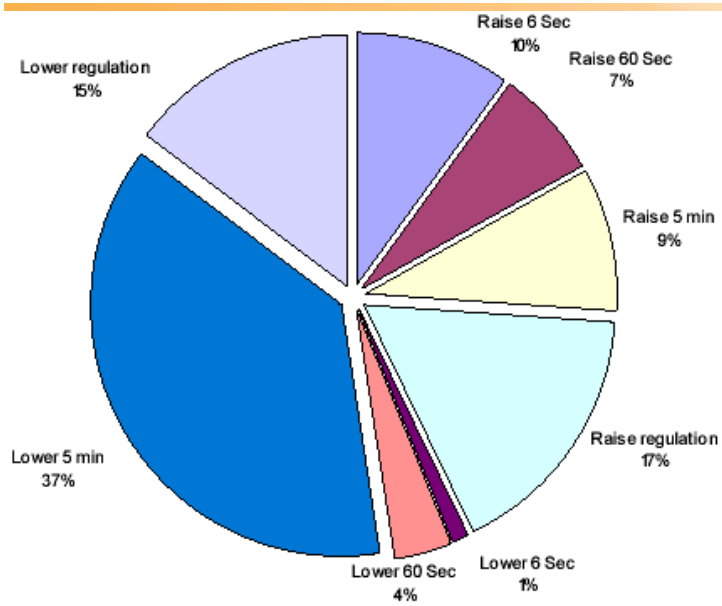
(Performance of the ancillary service markets, NECA May 03)

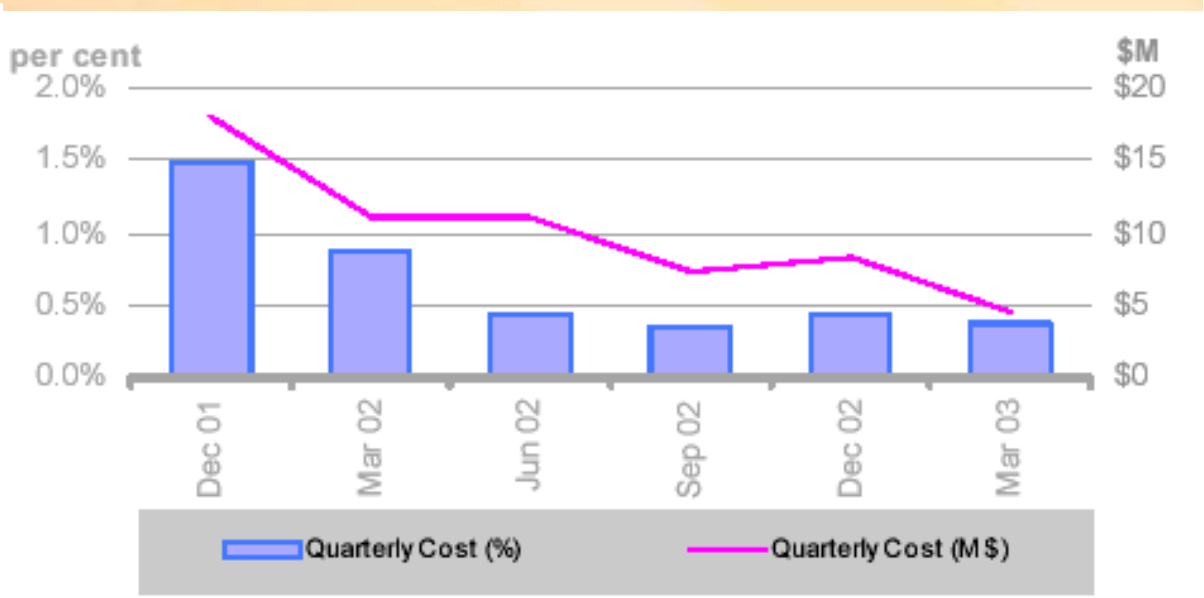


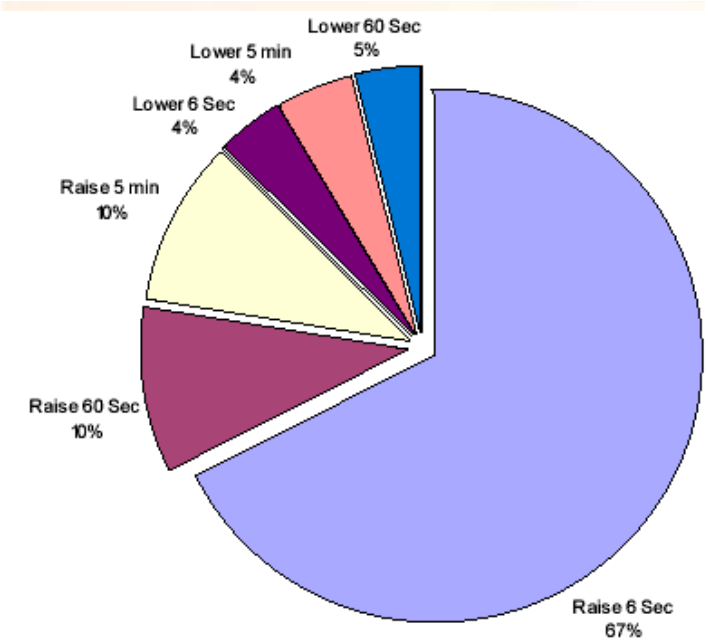
FCAS ancillary services around 50% of total AS cost since 10/01

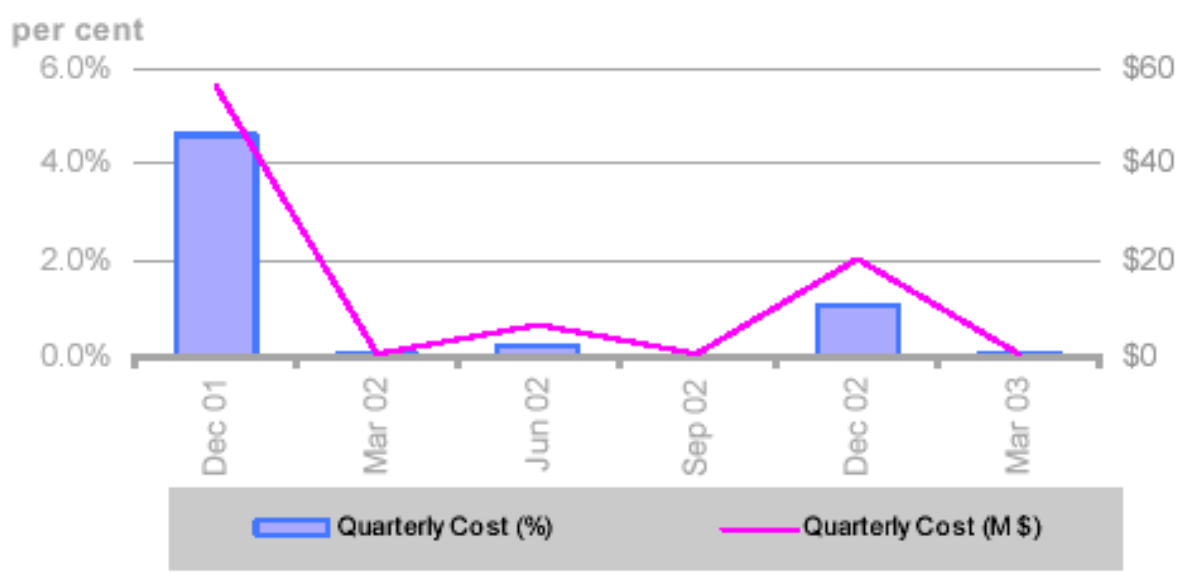
FCAS cost 10/01-3/03: sourced globally (top) & by region (bottom)

(Performance of the ancillary service markets, NECA May 2003)









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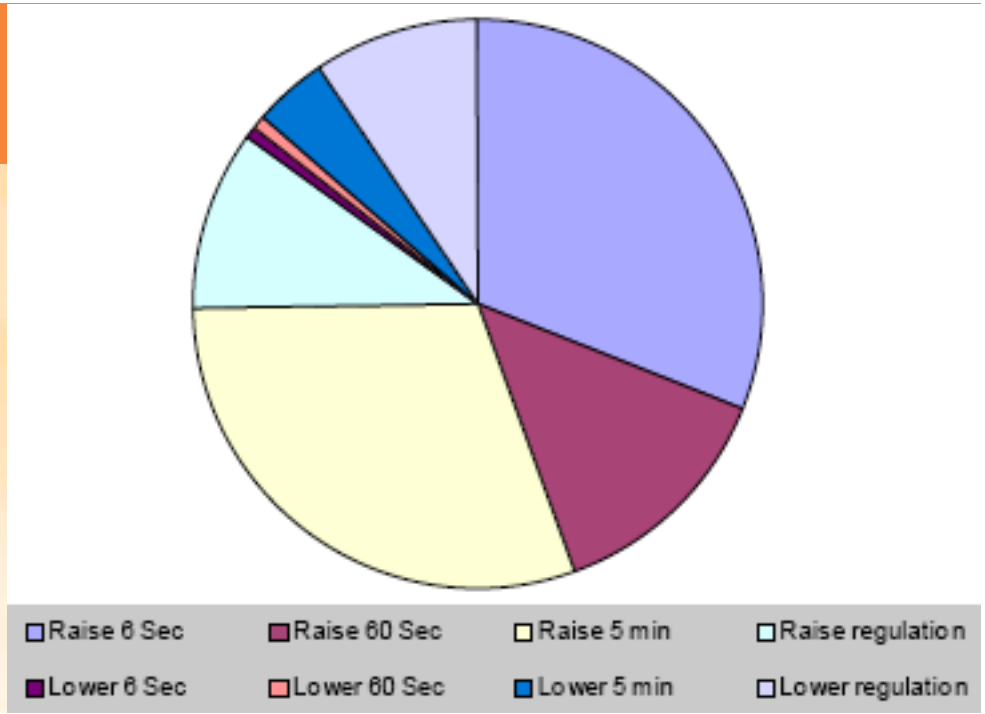
NEM FCAS market outcomes April-June 2004

(NECA 04Q2 stats, 2004)



	Raise 6 Sec	Raise 60 Sec	Raise 5 min	Raise reg	Lower 6 Sec	Lower 60 Sec	Lower 5 min	Lower reg	Total Cost
VWA price	$1.92	$0.82	$1.58	$1.28	$0.20	$0.25	$0.76	$1.17	-
VWA price (previous quarter)	$3.17	$2.77	$1.82	$2.23	$6.25	$5.54	$3.01	$2.17	-
Market Cost ($1,000 s)	$1,386	$594	$1,337	$464	$23	$31	$184	$424	$4,444
% of energy market	0.2%	0.1%	0.2%	0.1%	0.0%	0.0%	0.0%	0.1%	0.7%
% of AS market	31.2%	13.4%	30.1%	10.4%	0.5%	0.7%	4.1%	9.5%	100%

Review of FCAS markets

- ACCC determination on Regional Pricing of Ancillary Services, 17/9/03:
  - Participants in each region will bear costs when prices set by region
  - NECA to undertake a broader review
- Theoretical underpinnings of current FCAS arrangements appear to be weak

Relationship between main commercial markets & physical reality

Commercial disturbances

Main commercial markets

Spot & FI markets:

- Set commodity targets for ancillary services
- Manage persistent physical disturbances
- Manage commercial disturbances

Spot market energy targets

Unresolved physical disturbances

Projected cost of meeting future targets

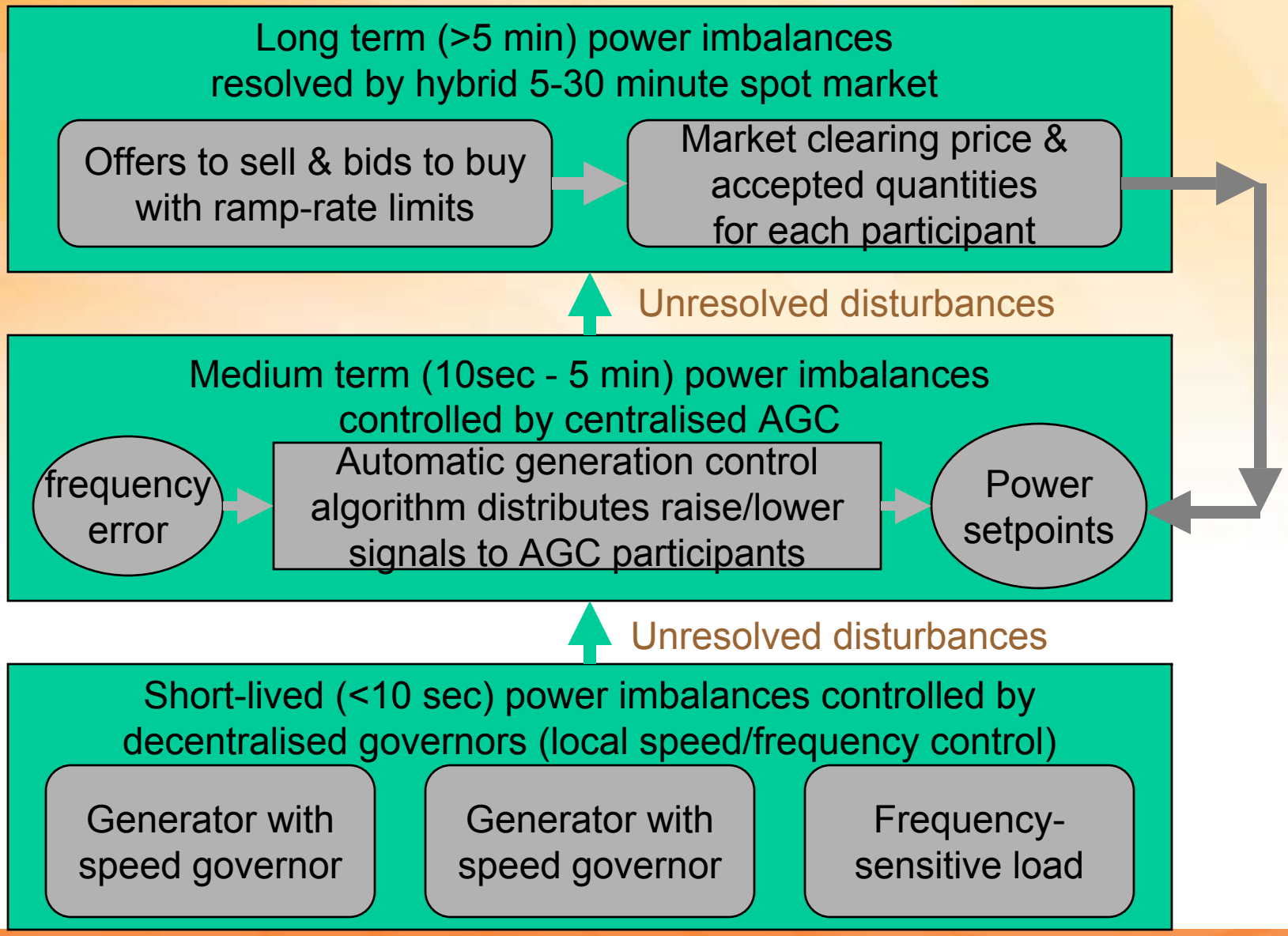
Physical disturbances

Physical reality

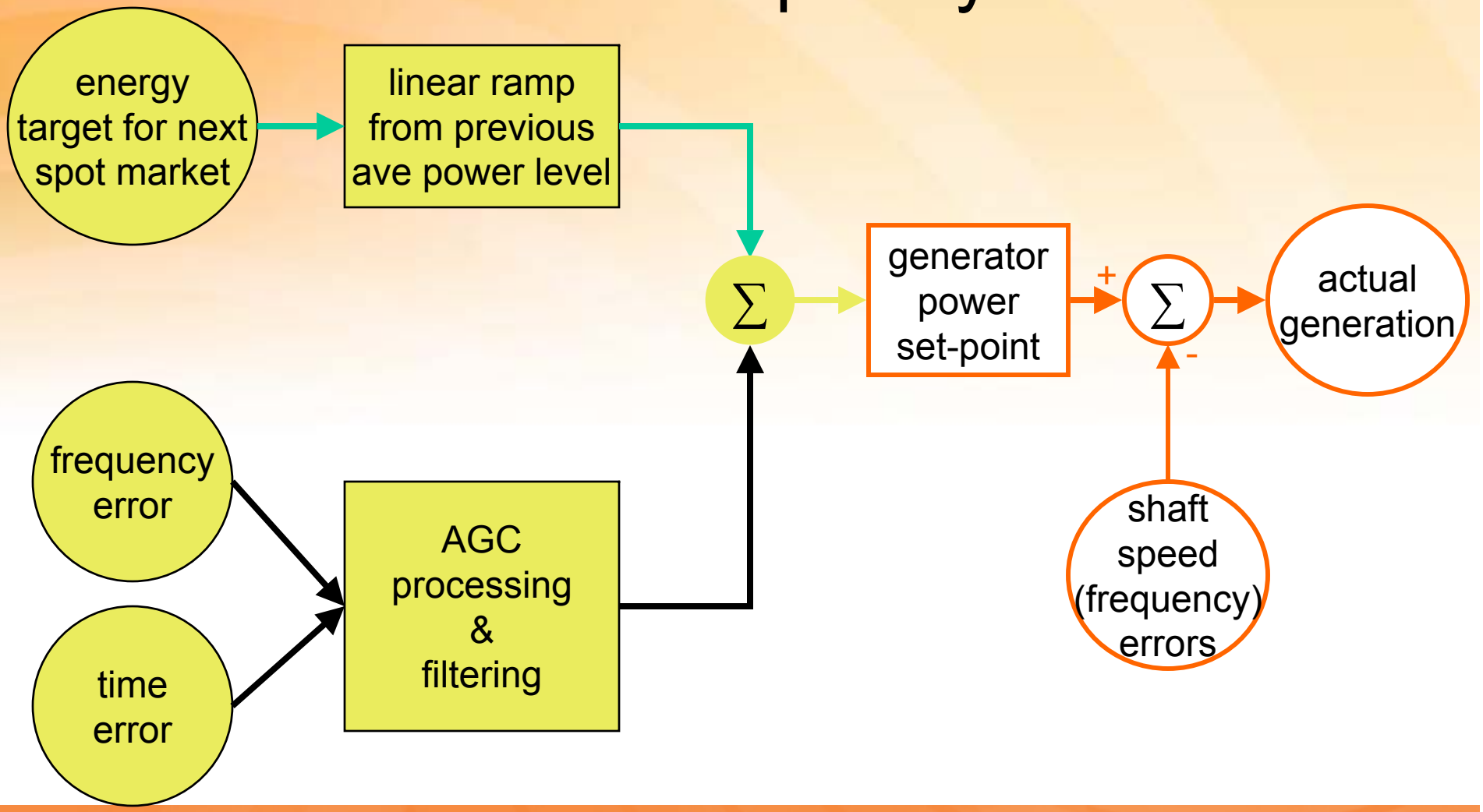
Ancillary services:

- Direct physical behaviour towards future energy targets
- Reject physical disturbances
- *Sufficient for expected tasks*

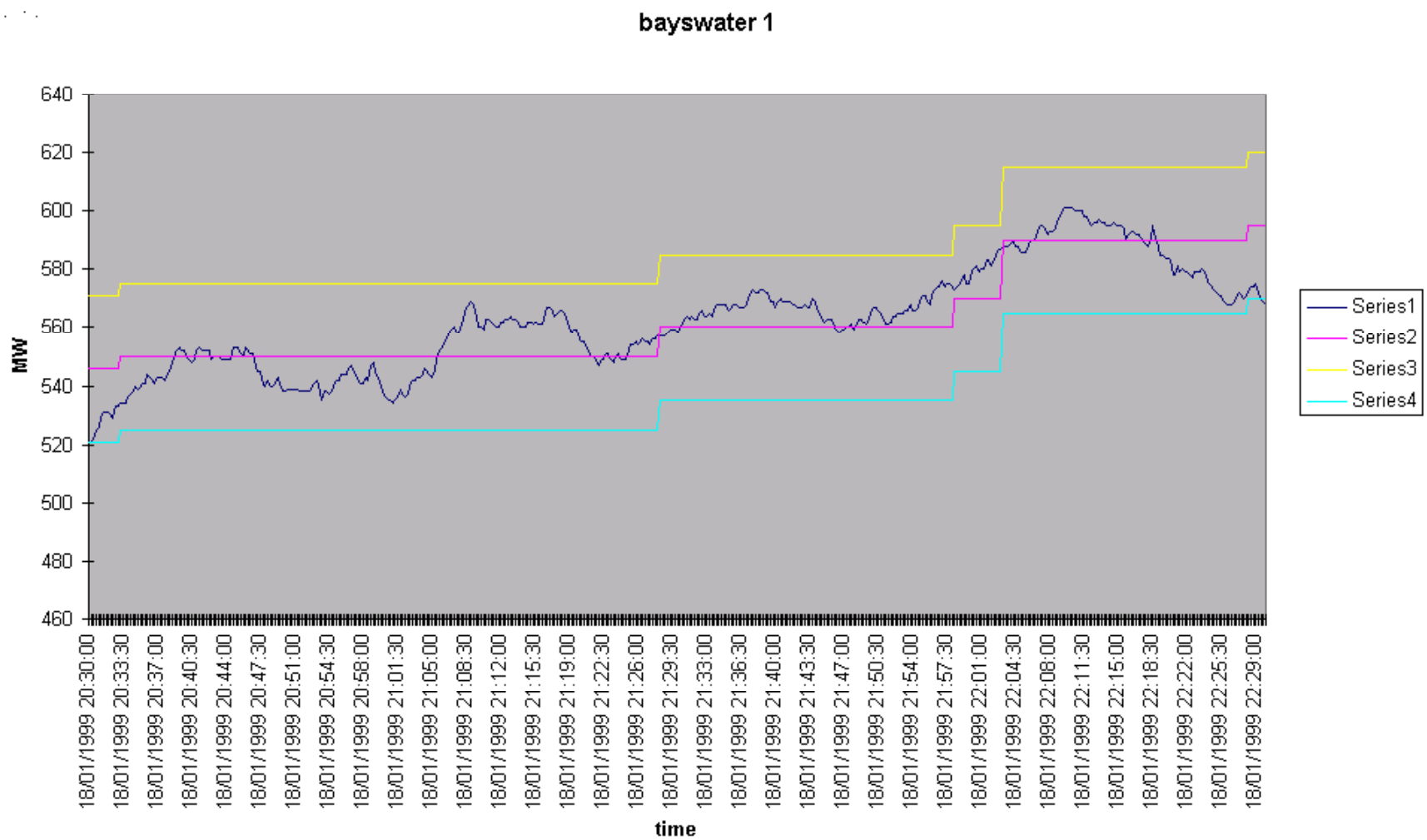
frequency control & NEM 5-30 minute spot market



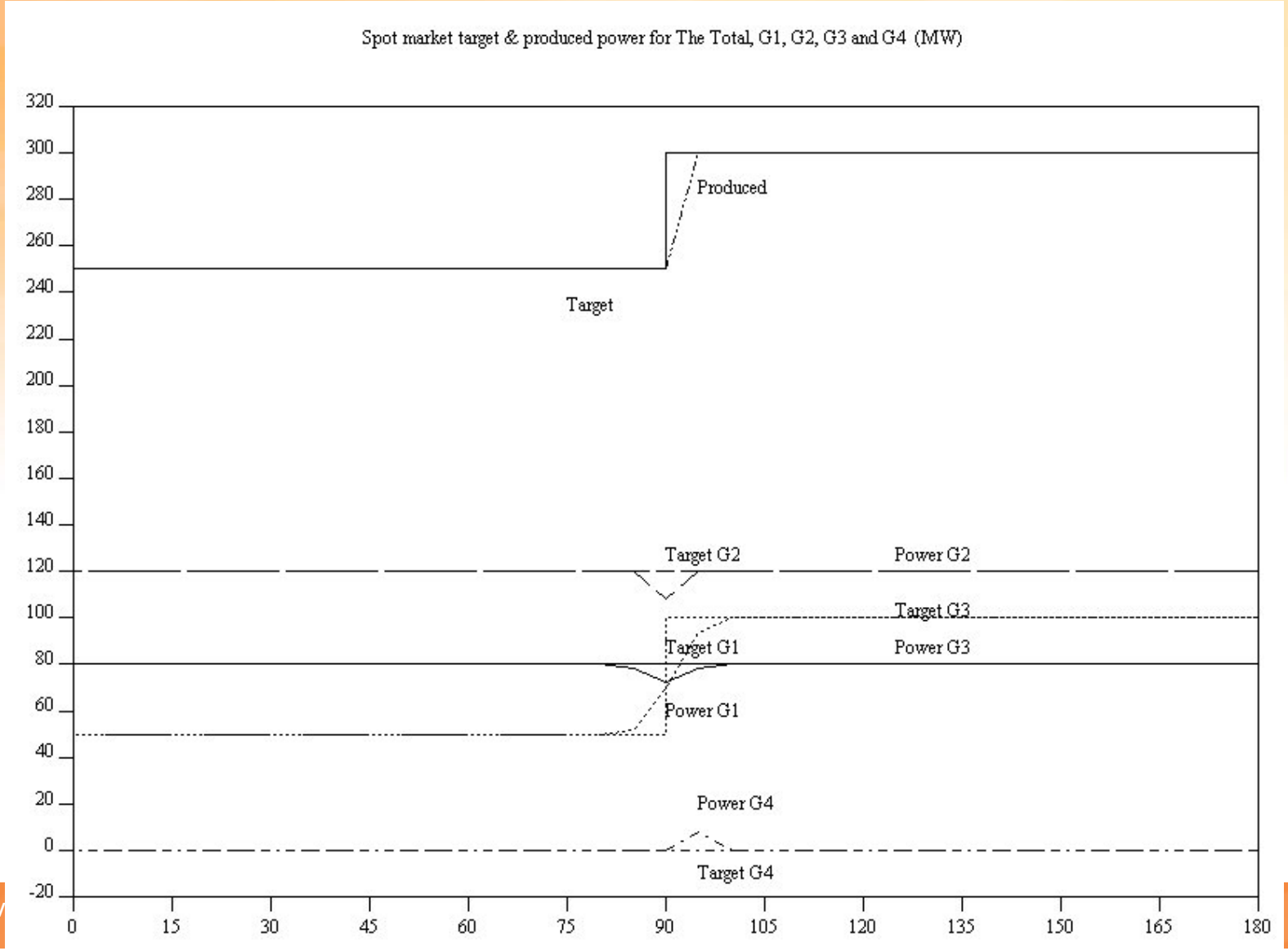
A generator responding to dispatch & small disturbance frequency control



A generator tracking five-minute dispatch targets with AGC raise/lower bounds



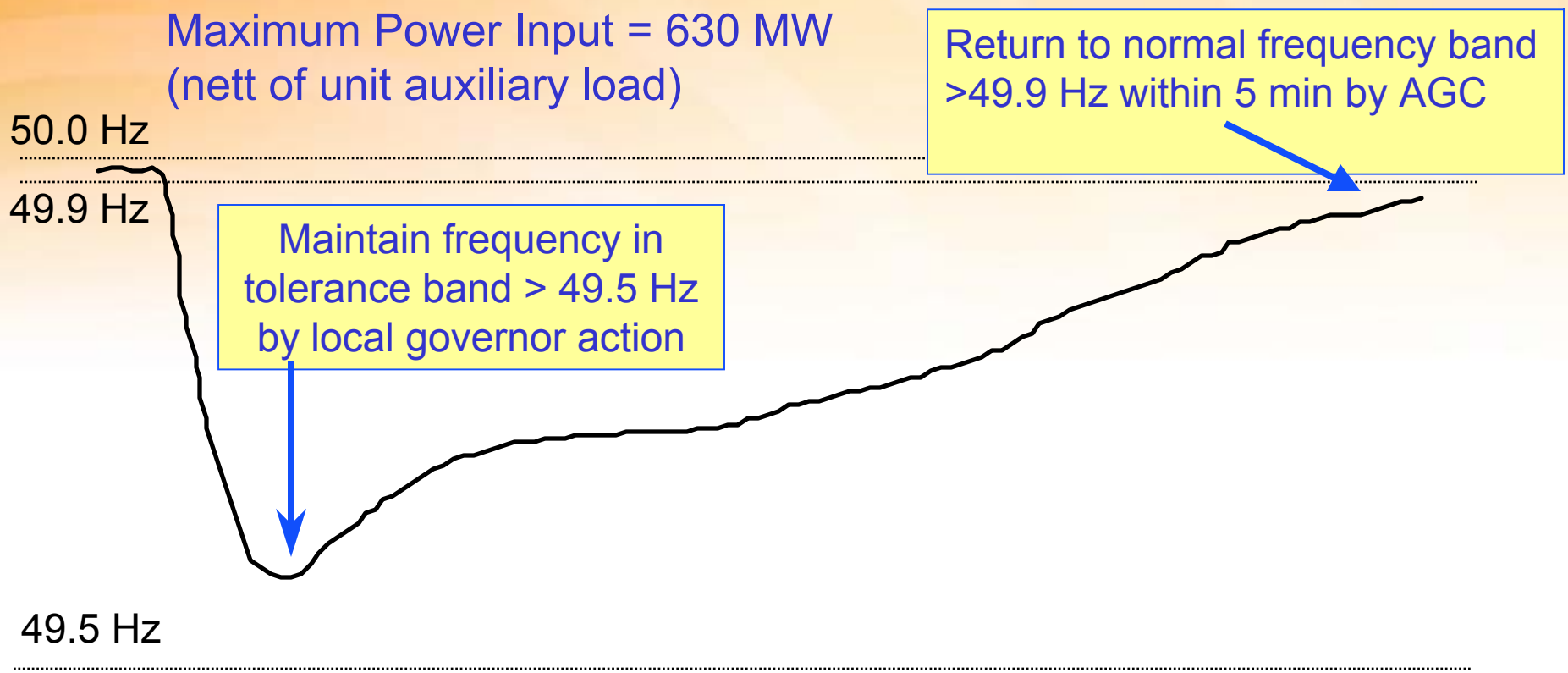
Finite horizon ramping control (Samuelsen, 2001)



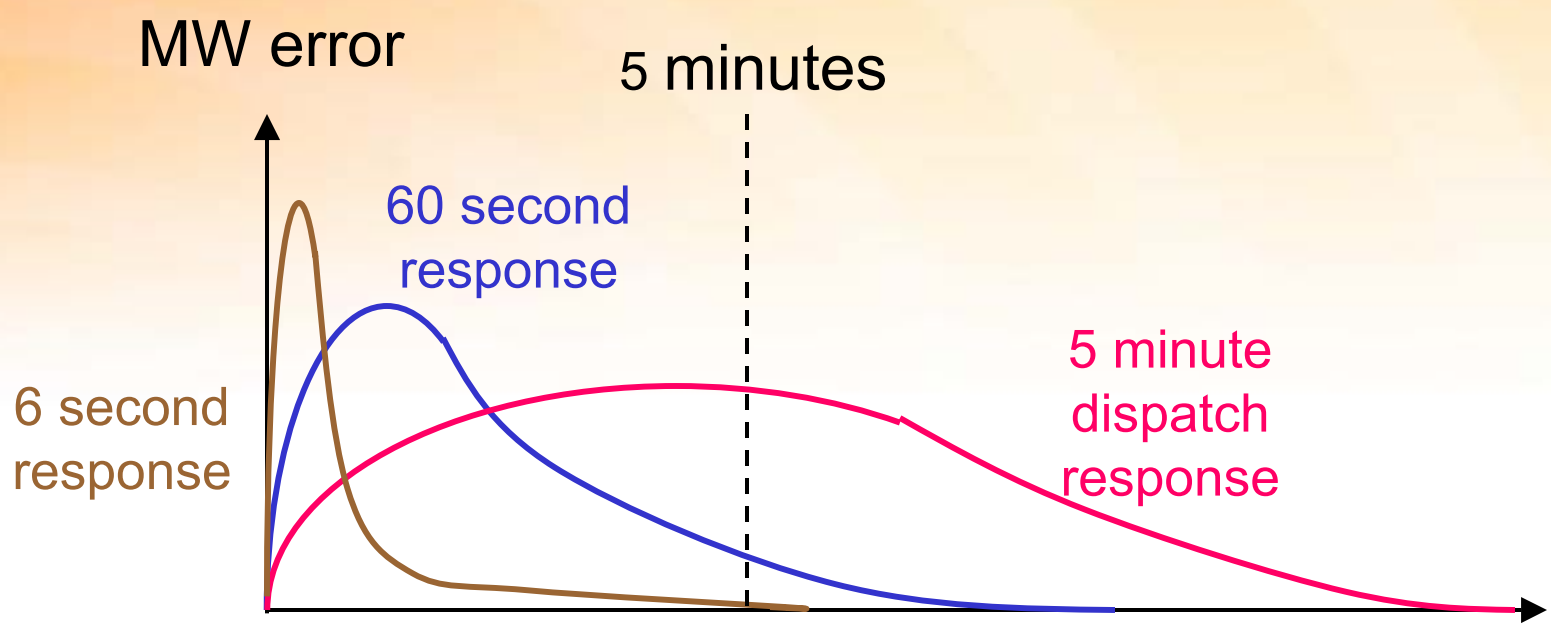
Large disturbance frequency control: loss of NSW 660 MW Generator

(source: NEMMCO)

Frequency control capability requirement = R



Indicative AS response to a unit outage

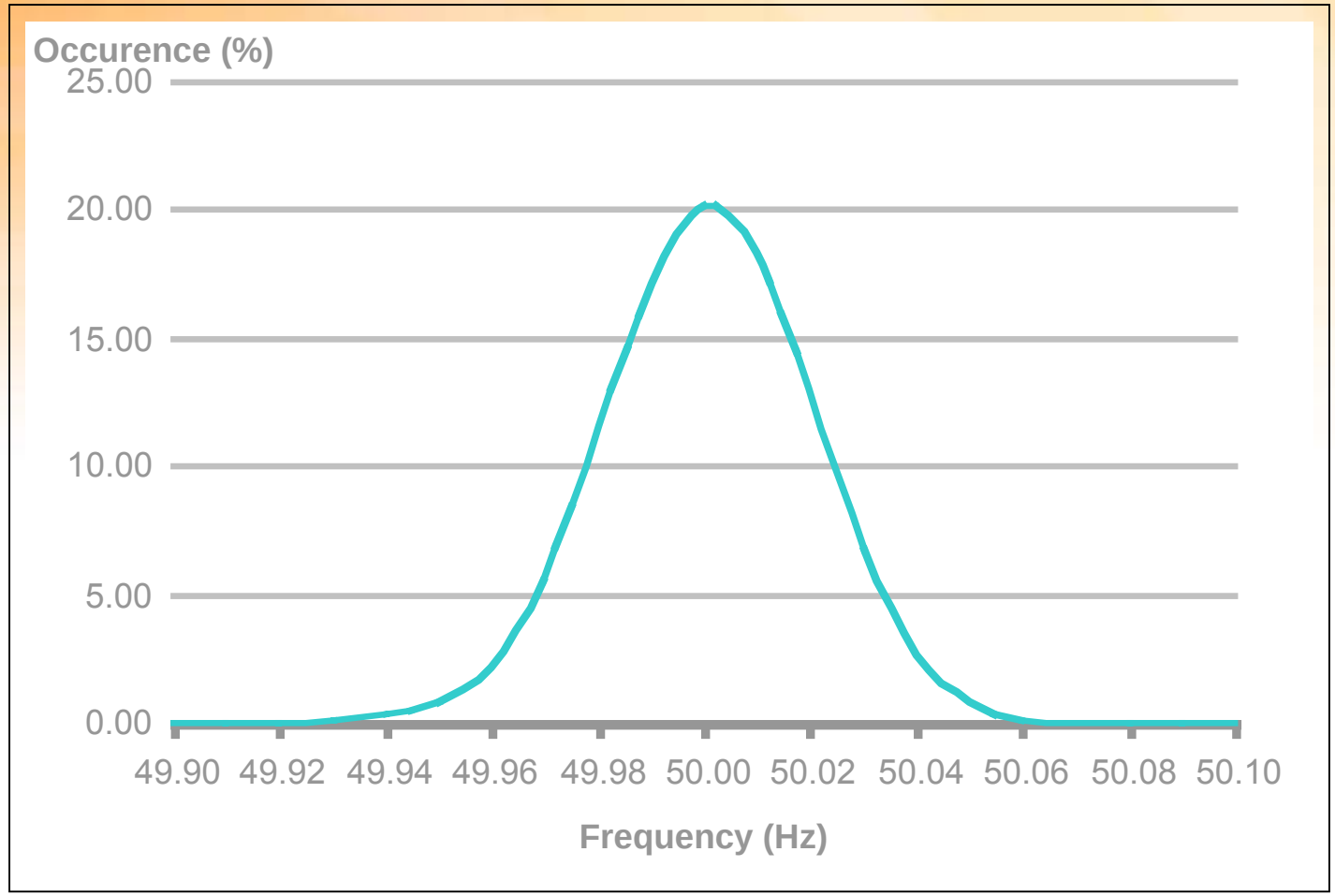


NEM frequency tolerance bands

State	Frequency band (Hz)
Normal	49.85 Š 50.15 (99% of time) 49.75 Š 50.25 (1% of time)
Single generator contingency	49.5 Š 50.5
Other credible contingency	49.0 Š 51.0
Emergency	47.0 Š 52.0

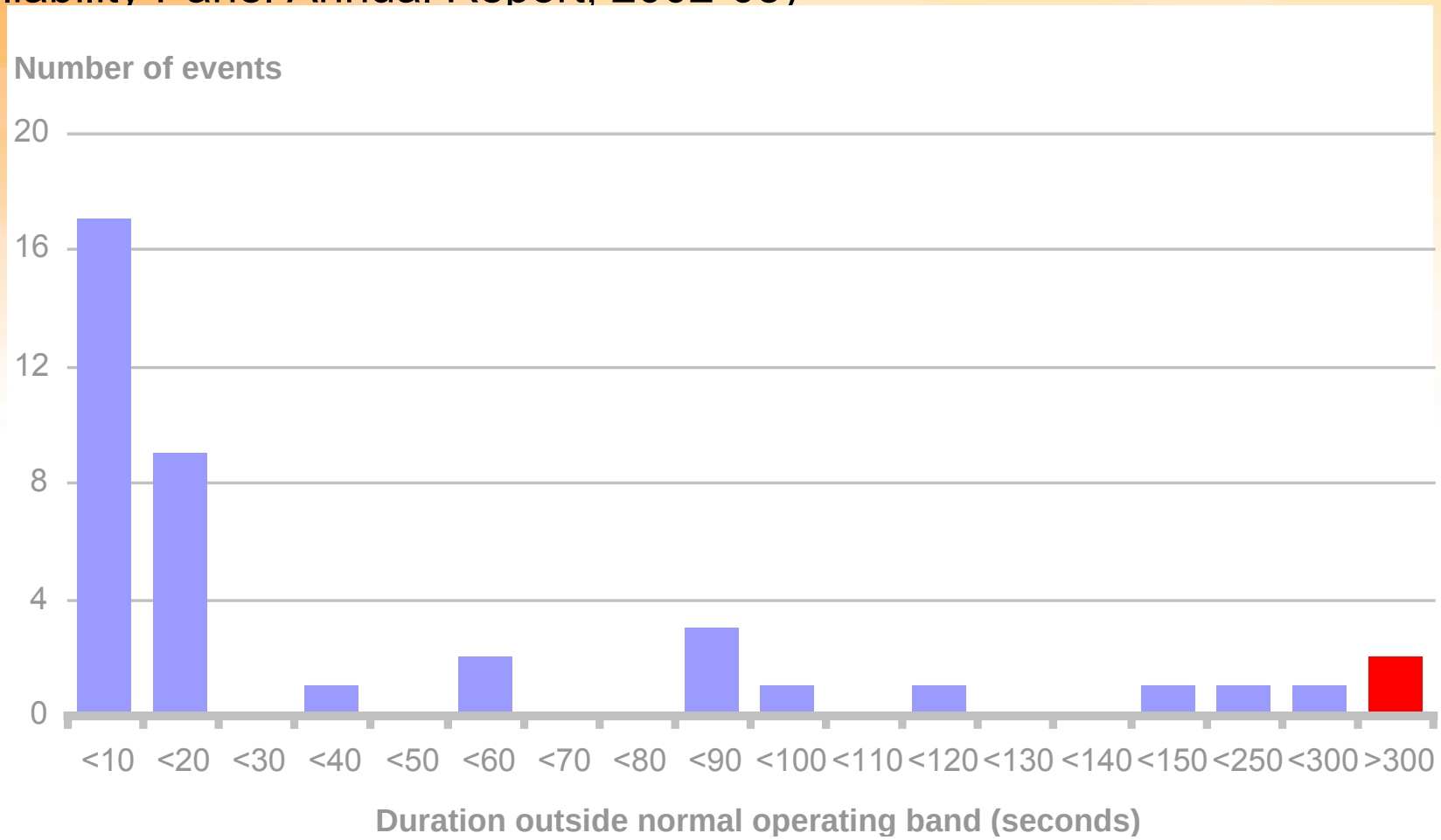
Distribution of frequency in the NEM, June 2003

(Reliability Panel Annual Report, 2002-3)



Frequency events outside the normal operating band in the NEM due to contingencies, 2002-03

(Reliability Panel Annual Report, 2002-03)

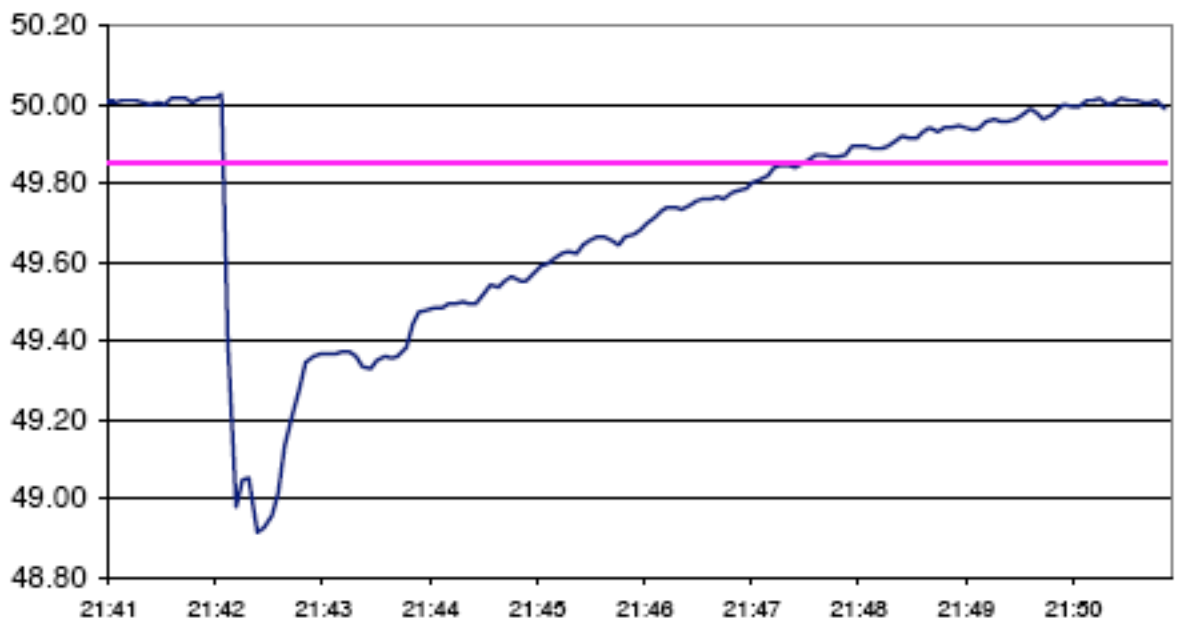


Power system disturbance, Friday 13/8/04

(http://www.nemmco.com.au/operating/systemops/232-0020.htm)

Current transformer failure at 2142caused 6 generators to trip with loss of ~3100 MW of generation. Frequency fell to 48.9Hz, ~2100 MW load shed

Generating unit	Output MW	Protection
Bayswater unit 1	658	Generator Differential Protection
Bayswater unit 2	654	Generator Differential Protection
Bayswater unit 3	659	Generator Differential Protection
Vales Point unit 6	542	Excitation Protection
Eraring unit 2	424	Negative Phase Sequence
Redbank	150	Under Frequency and Under Voltage



Responses by generation and load

Region	Load Block	Load Shed (MW)	Region Total (MW)
SA	Pasminco Port Pirie	18	25
	Block 2 (SA Water)	7	
VIC	1st Alcoa Portland Pot Line	279	488
	Alcoa Pt. Henry Pot Line	119	
	V4 (Alcoa Pt Henry Pot Line)	90	
NSW	Tomago No.1 Pot Line	296	480
	Capral No. 1 Pot Line	96	
	Capral No. 2 Pot Line	88	
QLD	Q1 (Ergon & Energex Customers)	314-340	500 - 550
	Q5 (Ergon & Energex Customers)	186-210	
			1493 - 1543

Also ~350MW load tripped on under voltage

Region	Initial Generation	Increase (as measured 1 minute after event)
QLD	5890	390
NSW	8960	-2800
VIC	6465	200
SA	1150	145
Snowy	100	330

Net loss of generation then ~1900MW, approximately equal to reduction in load

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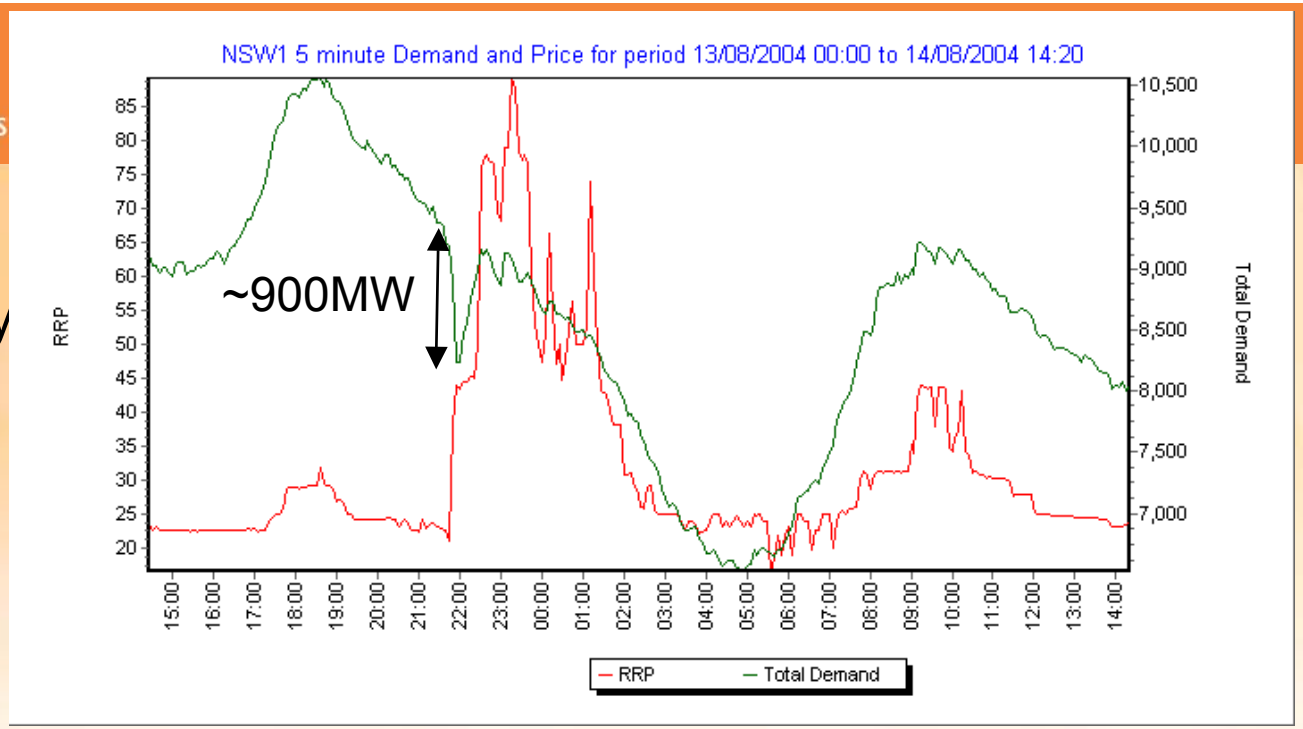
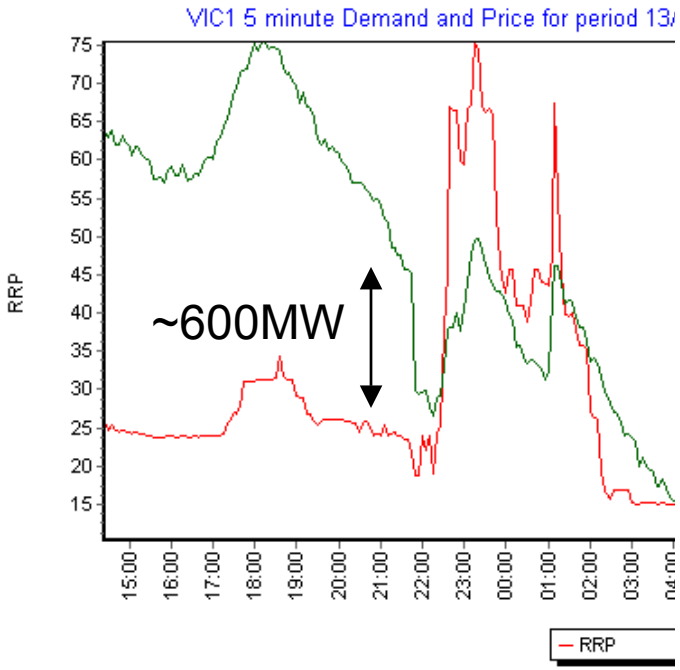
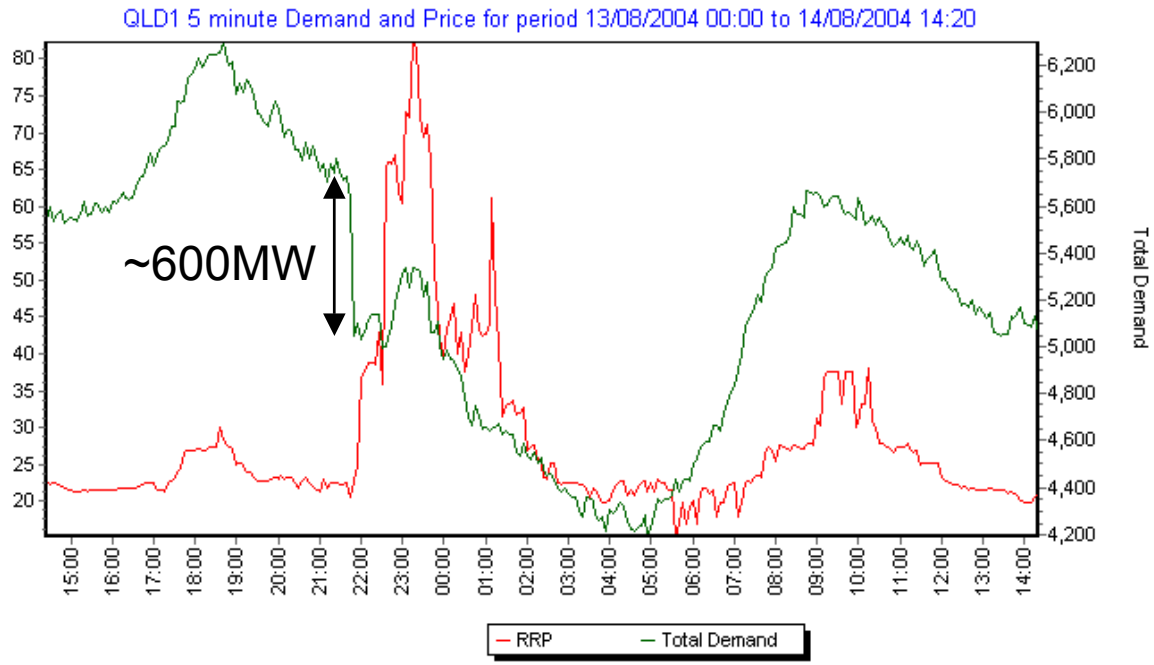
5-minute demand & price graphs for the day of the disturbance

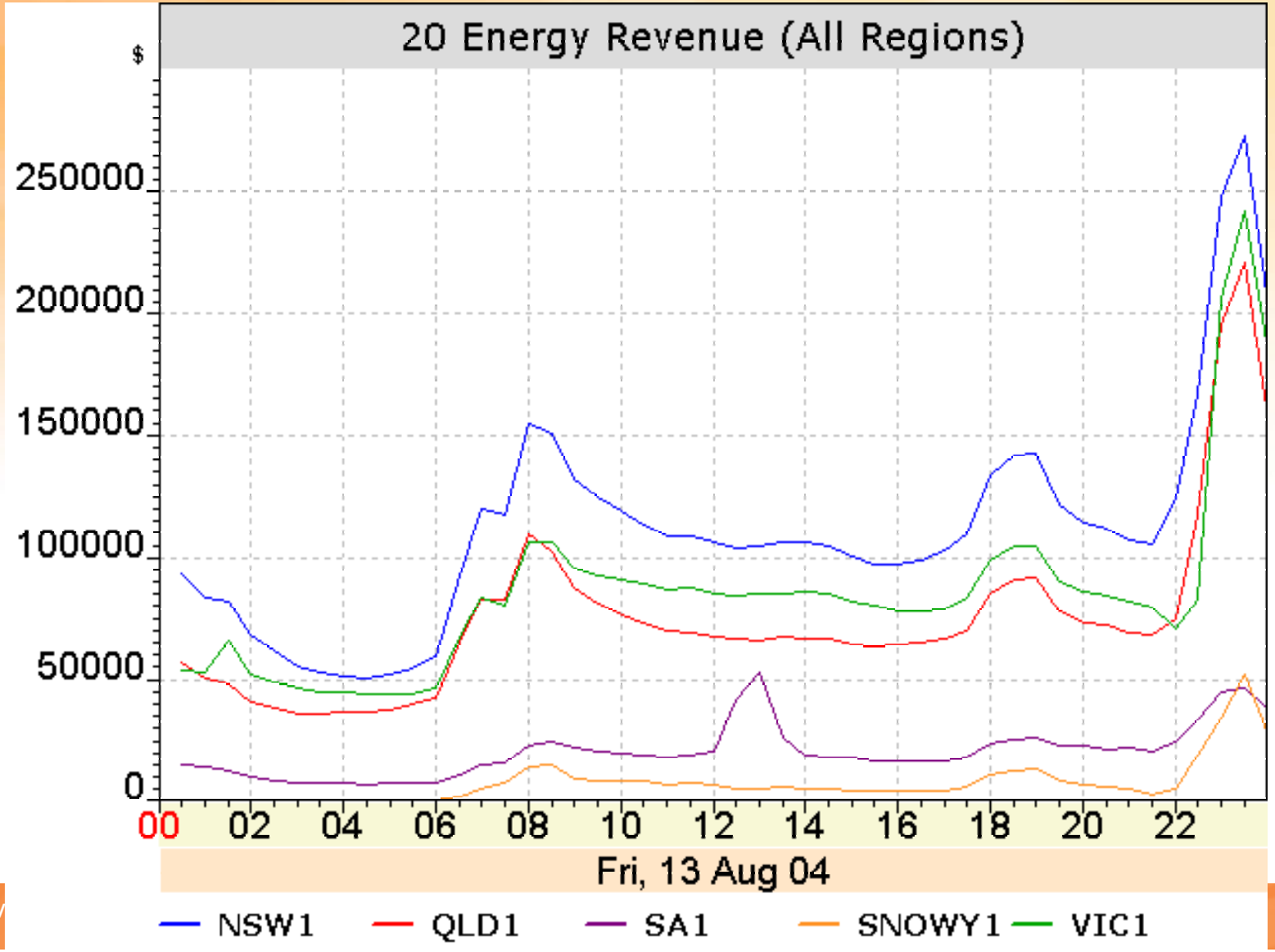
(www.nemmco.com.au)



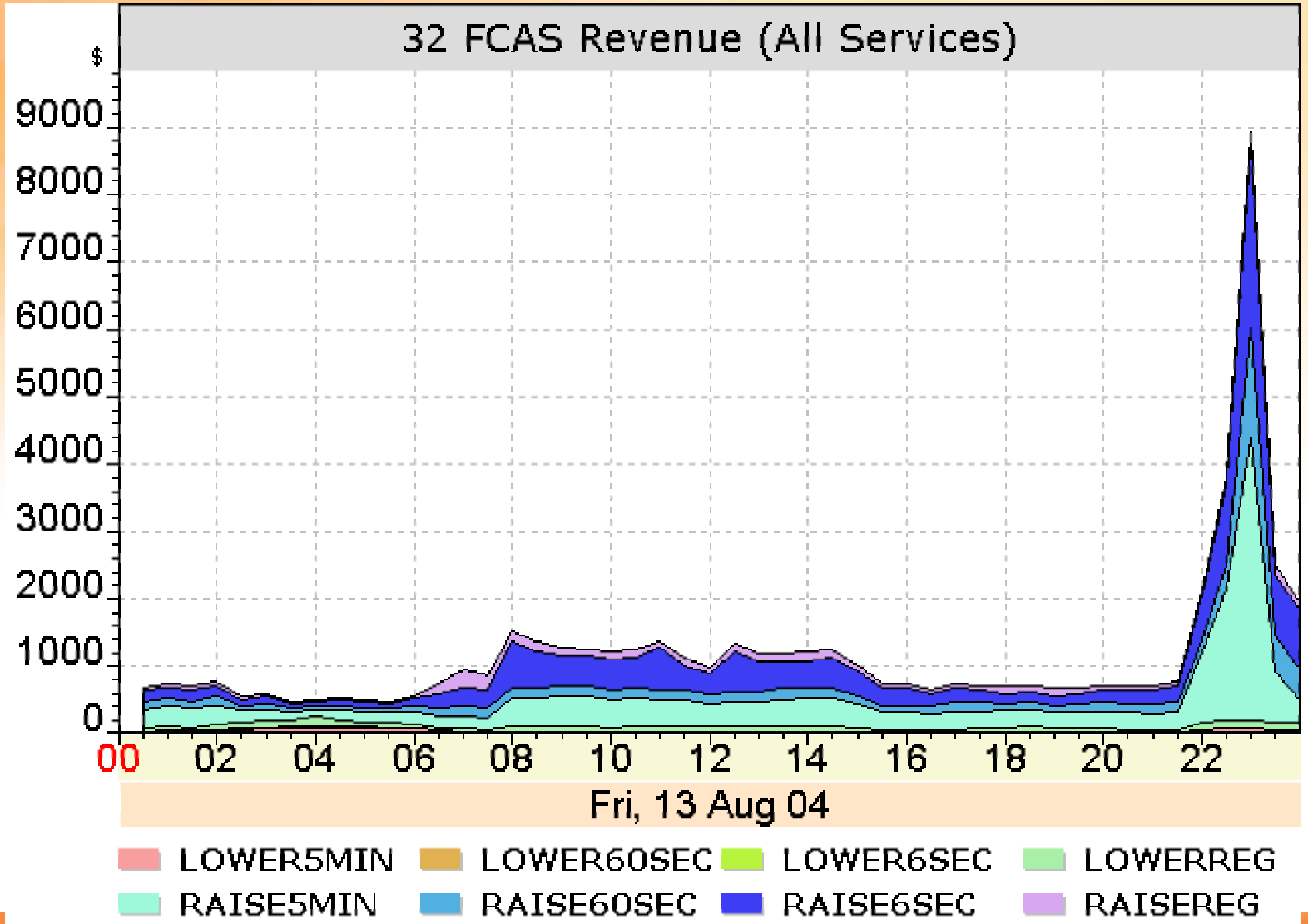




NEM energy revenue, 13/8/04



NEM FCAS revenue 13/8/04



Network Control Ancillary Services (NCAS)

- Voltage control - continuous:
  - NEC requires tap changers
- Voltage control - contingency:
  - Reactive power resources for planned worst case conditions
  - Emergency schemes for plausible multiple contingencies
- Stability control
  - NEC requires generators to install stabilisers
    - To enhance small & large disturbance stability

Network Control Ancillary Services (continued)

- Network loading contingency control:
  - To control transmission line flows
  - To permit full utilisation of transmission lines

System Re-start Ancillary Services

- Power station self-start capability
- Early restoration of supply to major cities

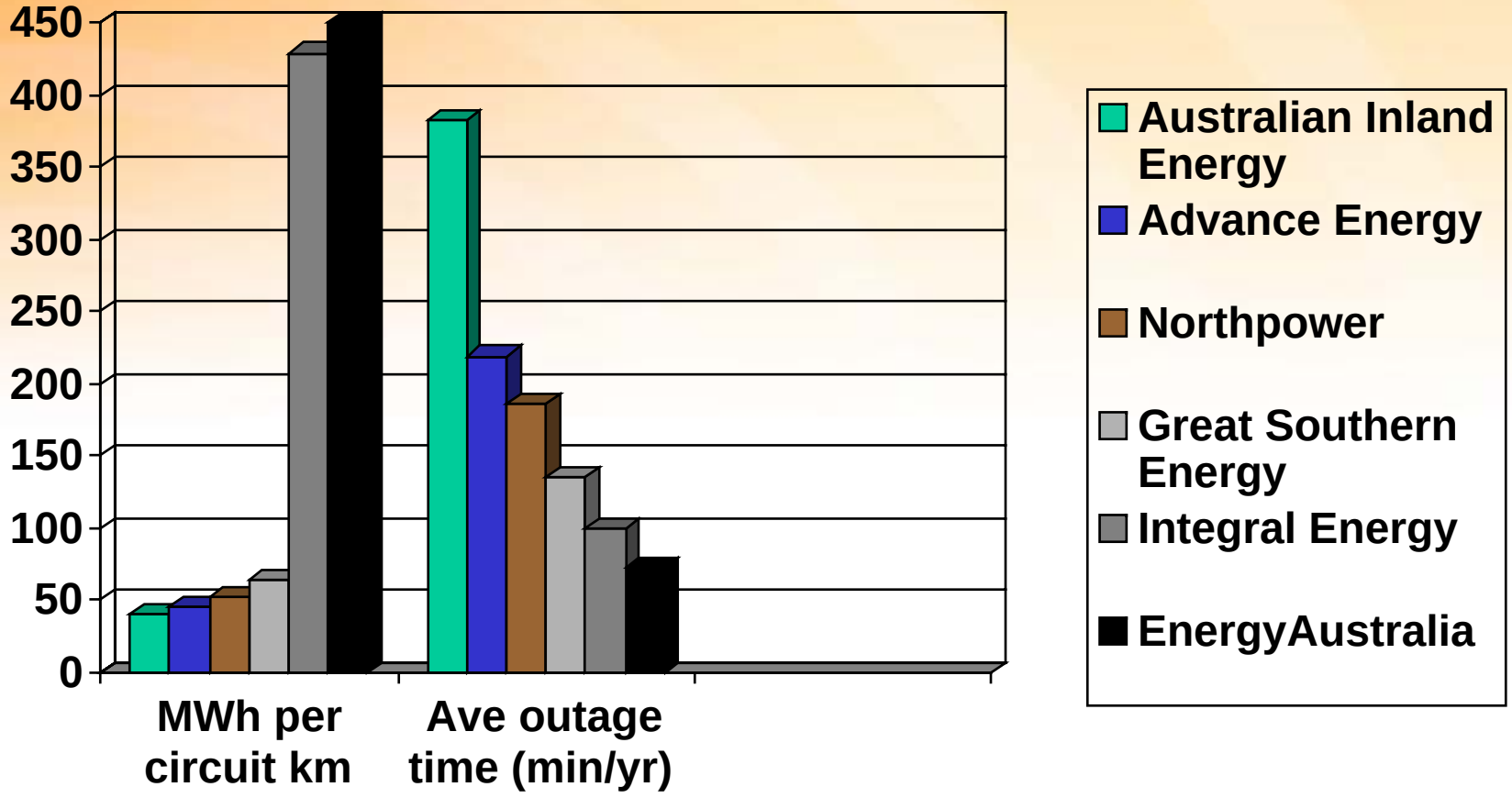
A distribution network perspective on ancillary services

- Transmission level ancillary services have little impact on distribution network QOS:
  - Voltage regulation, waveform purity, phase balance & supply availability
- Distribution level ancillary services may also address transmission level QOS:
  - e.g. frequency & stability-related services
- Thus distribution-level AS may have greater value than transmission level AS

Quality of supply in distribution networks

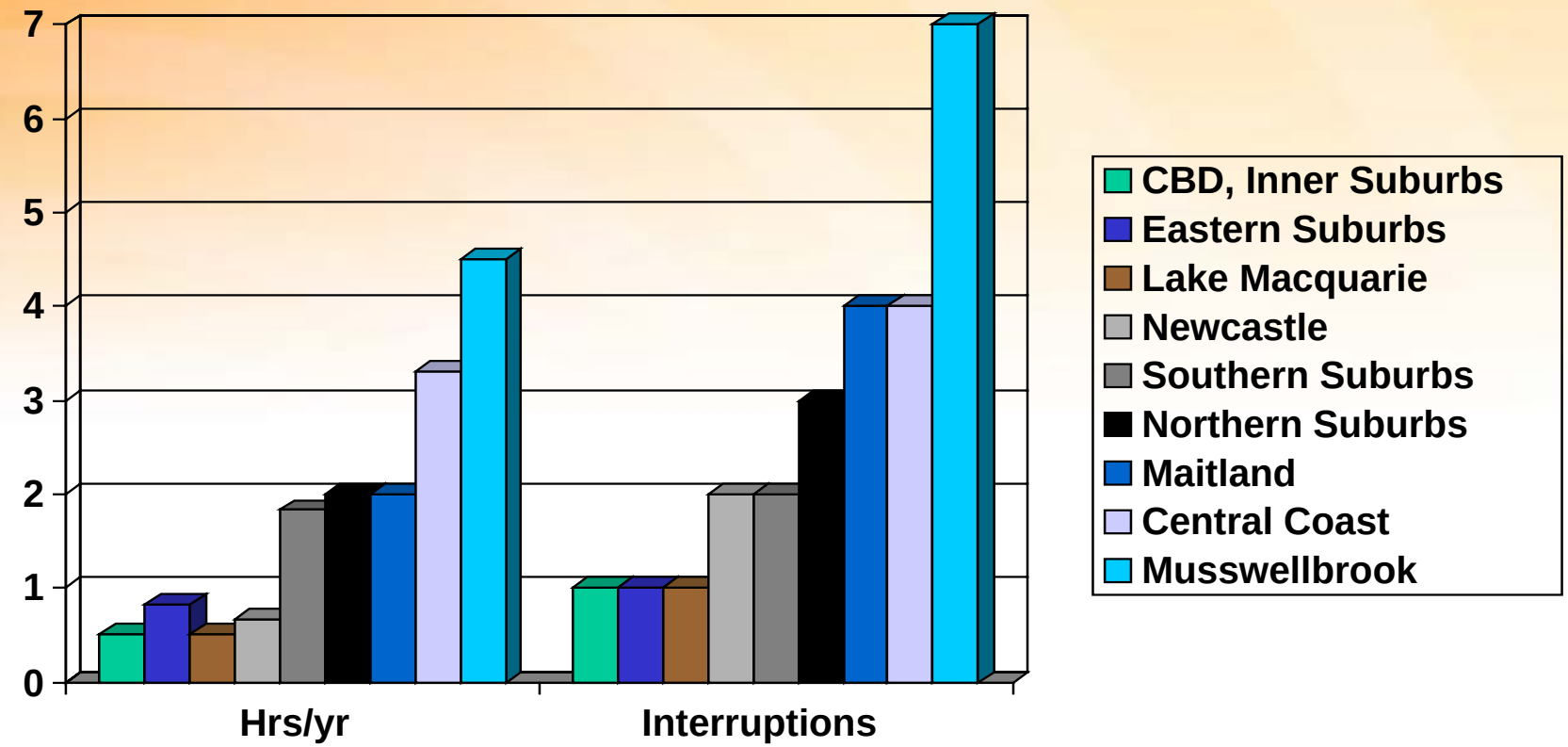
- Quality of supply attributes (QOS):
  - Voltage, frequency, waveform purity
  - Supply availability
- Practical network can't achieve perfect QOS:
  - Supply availability can vary widely within distribution networks
  - Poor QOS can cause electrical equipment to malfunction
  - Customer equipment can affect QOS

Energy density & reliability of NSW Distributors (IPART, 1996/97)



Average reliability in EnergyAustralia regions

(EnergyAustralia Electricity Supply Standards, 1998)

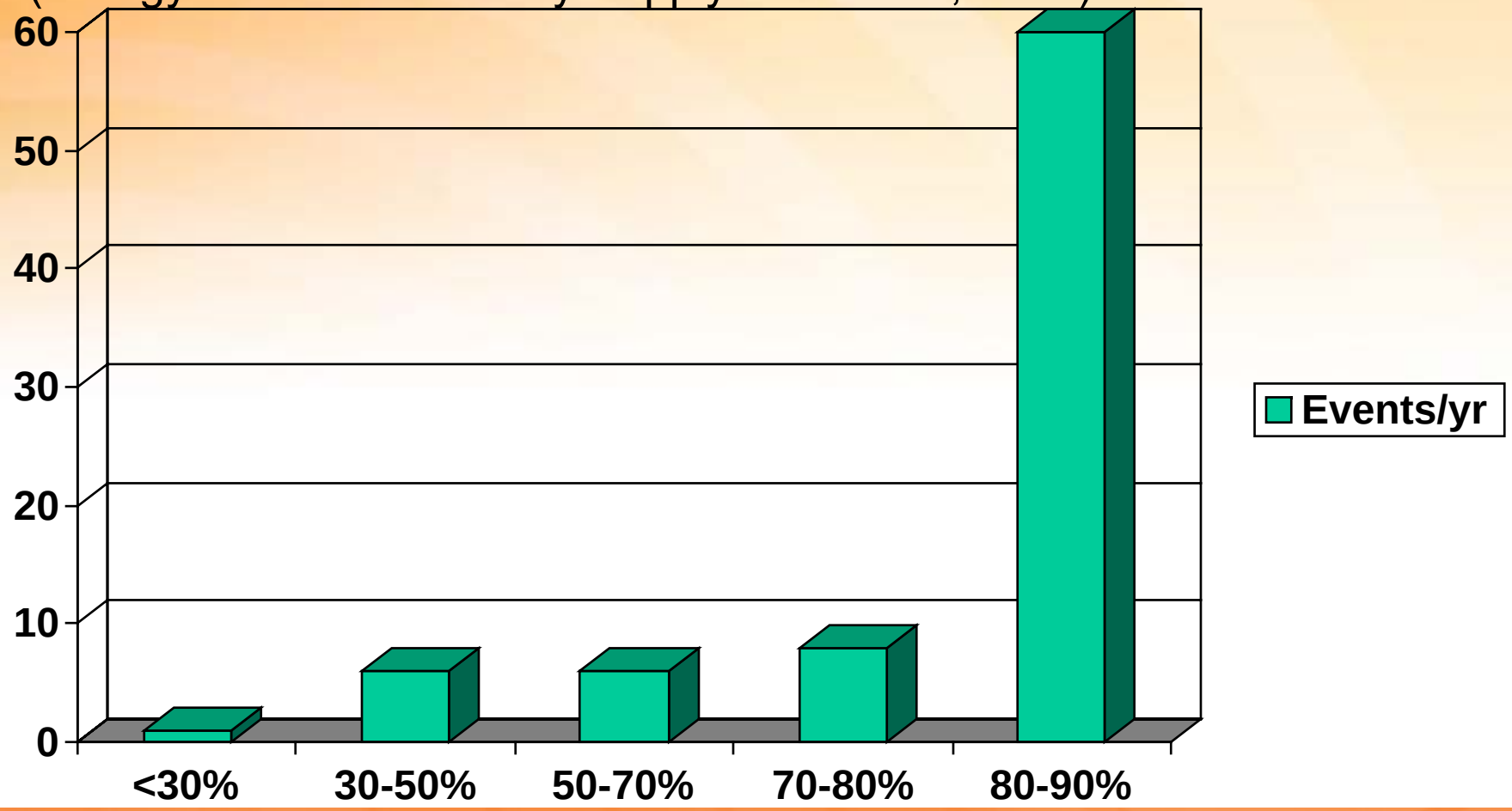


IPART's recommended guaranteed customer service standards (IPART, 2004)

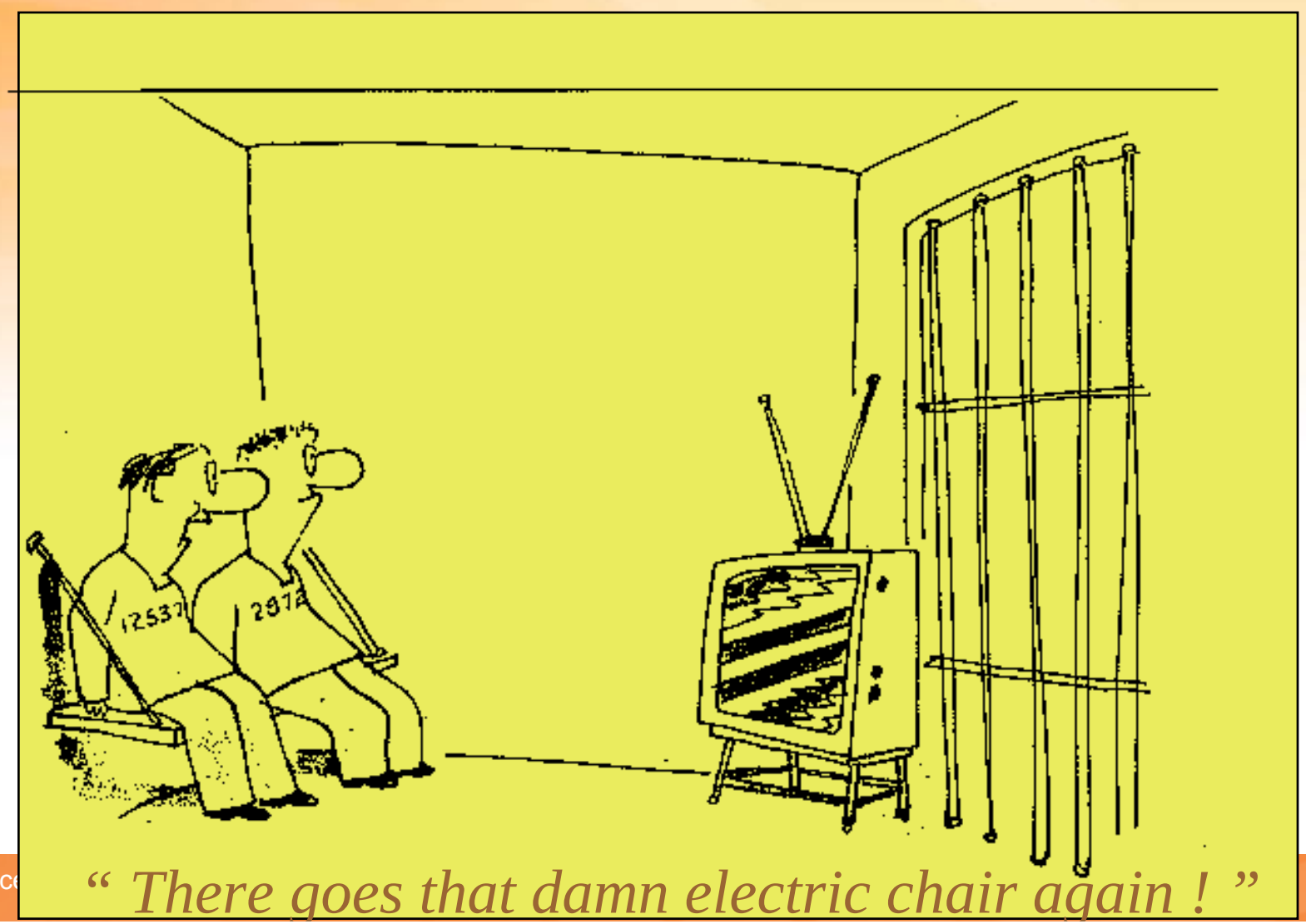
- Compensate customers on application if the number of outages per financial year exceed:
  - For EnergyAustralia & Integral:
    - 9 for customers on urban feeders
    - 15 for customers on rural feeders
  - For Country Energy & Australian Inland Energy:
    - 12 for customers on urban feeders
    - 20 for customers on rural feeders
- Compensate all DNSP customers on application if an individual outage exceeds 12 hours
- Up to a limit of 4 payments per year per customer

Average voltage dip events in EnergyAustralia service territory

(EnergyAustralia Electricity Supply Standards, 1998)



One piece of electrical equipment may interfere with another



" There goes that damn electric chair again ! "

Conclusions

- Ancillary services are an essential part of a competitive electricity industry:
  - Required to maintain availability & quality of supply
  - Critical in determining the need for investment
- AS most important at consumer nodes:
  - Primarily distribution rather than transmission issue
  - AS presently dealt with at the wholesale level:
    - Bias towards large participants
- Australian approach to AS is still evolving:
  - Unresolved issues include boundary problems